What is claimed is:

1. A volume hologram comprising a plurality of diffractive elements exhibiting a positional variation in at least one of amplitude, optical separation, and spatial phase over some portion of the thickness of the volume, the diffractive elements interacting with an input optical signal having a first spatial wavefront and a first optical spectrum to produce an output optical signal having a second spatial wavefront and a second optical spectrum, wherein the first spatial wavefront differs from the second spatial wavefront, and wherein the first optical spectrum differs from the second optical spectrum.

2. The volume hologram of claim 1 wherein the first spatial wavefront originates from an input optical waveguide.

3. The volume hologram of claim 1 wherein the second spatial wavefront converges to an output optical waveguide.

4. The volume hologram of claim 1 further comprising a bulk substrate.

5. The volume hologram of claim 1 where the hologram resides within a planar waveguide.

6. The volume hologram of claim 1, where each of the diffractive elements has a spherical contour and a center of curvature.

7. The volume hologram of claim 6, wherein the centers of curvature of a plurality of the diffractive elements are coincident.

8. The volume hologram of claim 7, wherein the input optical signal originates from an input waveguide and the output optical signal converges to an output waveguide, the respective input and output waveguides located at respective

conjugate image points of the plurality of the diffractive elements whose centers of curvature are coincident.

9. The volume hologram of claim 1 wherein the propagation direction of the input optical signal is not collinear to the propagation direction of the output optical signal.

10. The volume hologram of claim 1 wherein the input optical signal is an optical pulse.

11. The volume hologram of claim 1, further comprising a programmed spectral transfer function comprising a conjugate Fourier transform $E_i^*(\omega)$ of a design temporal waveform $E_i(t)$.

12. A volume hologram comprising:

a plurality of diffractive elements exhibiting a positional variation in at least one of amplitude, optical separation, and spatial phase over some portion of the thickness of the volume, the volume hologram interacting with an input optical signal having a first spatial wavefront and a first temporal waveform to produce an output optical signal having a second spatial wavefront and a second temporal waveform, wherein the first and second spatial wavefronts differ in at least one of spatial wavefront shape and output direction, and the first temporal waveform differs from the second temporal waveform.

13. The volume hologram of claim 12 wherein the input optical signal comprises an optical pulse.

14. The volume hologram of claim 12 wherein the first spatial wavefront originates from an input optical waveguide.

15. The apparatus of claim 12 wherein the second spatial wavefront converges to an output optical waveguide.

16. The volume hologram of claim 12, wherein the volume hologram is an optical waveform cross-correlator.

17. The volume hologram of claim 12, further comprising a programmed temporal transfer function, comprising a conjugate Fourier transform $E_i^*(\omega)$ of a designed temporal waveform $E_i(t)$.

18. The volume hologram of claim 12, where each of the diffractive elements has a spherical contour and a center of curvature.

19 The volume hologram of claim 18, wherein wherein the centers of curvature of a plurality of the diffractive elements are coincident.

20. The volume hologram of claim 19, wherein the input optical signal originates from an input waveguide, and wherein the output optical signal converges to an output waveguide, with the respective input and output waveguides located at respective conjugate image points of the plurality of the diffractive elements whose centers of curvature are coincident.

21. The volume hologram of claim 12 wherein the first spatial wavefront originates from an input optical waveguide and the second spatial wavefront converges to an output optical waveguide, and the input waveguide is separated from the output waveguide by a distance equal to or less than about 5000 microns.

22. The volume hologram of claim 12 wherein the first spatial wavefront originates from an input optical waveguide and the second spatial wavefront converges to an output optical waveguide, and the input waveguide is separated from the output waveguide by a distance between about 5000 microns and about 25 microns.

23. The volume hologram of claim 12 wherein the propagation direction of the input optical signal is not collinear to the propagation direction of the output optical signal.

24. The volume hologram of claim 12 wherein all diffractive elements have an elliptical contour, with each diffractive element having a first focus and a second focus, and wherein a plurality of the respective first foci of the diffractive elements coincide, and a plurality of the respective second foci of the diffractive elements coincide.

25. The volume hologram of claim 24, wherein the input optical signal originates from an input waveguide and the output optical signal converges to an output waveguide, and where the respective input and output waveguides are located at the respective foci of the diffractive elements whose respective first foci coincide, and whose respective second foci coincide.

26. An apparatus comprising

an input port operative to launch an input optical signal having an input spatial wavefront and an input optical spectrum;

a volume hologram comprising a plurality of diffractive elements exhibiting a positional variation in at least one of amplitude, optical separation, and spatial phase over some portion of the thickness of the volume, the volume hologram interacting with an input optical signal having an input spatial wavefront and an input optical spectrum, to produce a plurality of output optical signals each with a respective output spatial wavefront and a respective output optical spectrum, at least one output optical signal whose output optical spectrum is distinguishable from the other output optical spectra and which has a direction of propagation that differs from the respective directions of propagation of all of the other output optical signals; and

a plurality of output ports, configured to accept and transmit the plurality of output optical signals.

27. The apparatus of claim 26 wherein the input optical signal comprises a plurality of wavelength-differentiated communication channels, and wherein at least one output optical signal comprises fewer than all of the plurality of wavelength-differentiated communication channels that comprise the input optical signal, the at least one output optical signal having a direction of propagation differing from the respective directions of propagation of the other output optical signals.

28. The apparatus of claim 26, wherein each output optical signal comprises a single wavelength-differentiated communications channel, and wherein each output optical signal is focused to a location that differs from the respective locations of focus of each of the other respective output optical signals.

29. The apparatus of claim 27, wherein at least one output optical signal comprises more than one wavelength-differentiated communications channel.

30. An apparatus comprising

a plurality of input ports, each operative to launch at least one of a plurality of input optical signals, each input optical signal having a spatial wavefront and an optical spectrum;

a volume hologram comprising a plurality of diffractive elements exhibiting a positional variation in at least one of amplitude, optical separation, and spatial phase over some portion of the thickness of the volume, the volume hologram interacting with the plurality of input optical signals having respective input spatial wavefronts and respective input optical spectra, to produce an output optical signal having an output spatial wavefront and an output optical spectrum; and

an output port configured to accept and transmit the output optical signal.

31. The apparatus of claim 30 wherein the plurality of input optical signals comprises a plurality of wavelength-differentiated communications channels.

32. The apparatus of claim 30 wherein each optical input signal comprises a single wavelength-differentiated communications channel.

33. The apparatus of claim 30 wherein at least one input optical signal comprises a plurality of wavelength-differentiated communications channels.

34. An apparatus comprising

an input port operative to launch an input optical signal having an input spatial wavefront and an input temporal waveform;

a volume hologram comprising a plurality of diffractive elements exhibiting a positional variation in at least one of amplitude, spatial separation, and spatial phase over some portion of the thickness of the volume, the volume hologram interacting with the input optical signal to produce a plurality of output optical signals, each output optical signal having a spatial wavefront that differs from the respective spatial wavefronts of all other output optical signals, each output optical signal having a respective temporal waveform, wherein at least two of the output optical signals have temporal waveforms that differ from one another; and

a plurality of output ports configured to accept and transmit the plurality of output optical pulses.

35. The apparatus of claim 34 wherein the input optical signal is an optical pulse.

36. A method comprising:

receiving from at least one input, an input optical signal having a first spatial wavefront and a first optical spectrum and a first direction of propagation in a volume hologram comprising a plurality of diffractive elements;

diffracting an input optical signal via the diffractive elements, producing a diffracted optical signal having an optical spectrum that differs from the input optical spectrum, the diffracted optical signal having second direction of propagation; and

transmitting the diffracted optical signal, the diffracted optical signal comprising a second spatial wavefront, wherein the first and second spatial wavefronts are not identical in shape.

37. The method of claim 36, wherein the volume hologram further comprises spatial transformation information.

38. The method of claim 36 wherein the propagation direction of the input optical signal is not collinear to the propagation direction of the diffracted optical signal.

39. The method of claim 36 wherein the input optical signal is an optical pulse.

40. The method of claim 37 wherein the processed optical signal is spatially transformed.

41. The method of claim 36 where the volume hologram further comprises temporal transformation information.

42. The method of claim 41 wherein the diffracted optical signal is temporally transformed.

43. The method of claim 37 where the volume hologram further comprises temporal transformation information.

44. The method of claim 43 wherein the diffracted optical signal is spatially and temporally transformed.

45. A method comprising:

receiving an input optical signal comprising a first temporal waveform, into an input coupled to a volume hologram comprising a transfer function that comprises temporal information, the volume hologram coupled to an output;

diffracting the optical signal via the diffractive elements, producing a diffracted optical signal comprising a second temporal waveform that differs from the first temporal waveform; and

directing the diffracted optical signal to the output.

46. The method of claim 45, wherein the volume hologram further comprises spatial transformation information.

47. The method of claim 46 wherein the diffracted optical signal is spatially transformed.

48. The method of claim 45 wherein the input optical signal has a first direction of propagation and the diffracted optical signal has a second direction of propagation, and where the first direction of propagation is not collinear to the second direction of propagation.

49. The method of claim 45 wherein the input optical signal is an optical pulse.

50. The method of claim 45 wherein the volume hologram further comprises spectral transformation information.

51. The method of claim 50 wherein the diffracted optical signal is spectrally transformed.

52. The method of claim 50, wherein the volume hologram further comprises spatial transformation information.

53. The method of claim 52 wherein the diffracted optical signal is spectrally and spatially transformed.

54. The method of claim 45, wherein the volume hologram is an optical waveform cross-correlator.

55. The method of claim 45, where the transfer function comprises a conjugateFourier transform E_I^* (ω) of a designed temporal waveform $E_I(t)$.

56. A method comprising:

calculating a temporal interference pattern produced by an interference of a chosen input signal $E_i(t)$ with an intended output signal $E_o(t)$, the chosen input signal and the intended output signal travelling within a common boundary in a common time frame.

57. The method of claim 56, further comprising calculating a plurality of temporal interference patterns produced by respective inteference of a plurality of chosen input signals $E_i(t)$ with a respective plurality of intended output signals $E_I(t)$, and where a total temporal interference pattern is calculated as a superposition of the plurality of temporal interference patterns.

58. A method comprising:

imprinting on at least one slab face of a substrate, a holographic pattern comprising temporal transformation information.

59. The method of claim 58 wherein the holographic pattern further comprises spatial transformation information.

60. The method of claim 58 wherein the imprinting is accomplished using a technique chosen from the group consisting of photolithography, electron beam lithography, stamping, etching, mechanical abrasion, ultrasonic material removal, heat deformation, laser ablation, photosensitive exposure, and combinations thereof.

61. The method of claim 58 wherein imprinting occurs on two faces of the substrate.

62. A product produced according to the method of claim 58.

63. A method comprising:

depositing a layer on at least one slab face of a substrate;

imprinting on the layer a hologram comprising temporal transformation information.

64. The method of claim 63 wherein the hologram further comprises spatial transformation information.

65. The method of claim 63 wherein the hologram further comprises spectral transformation.

66. The method of claim 63, wherein the imprinting occurs by deformation of the layer.

67. The method of claim 63, wherein the layer deposited is dielectric.

68. The method of claim 63, wherein the layer deposited is metallic.

69. A product produced according to the method of claim 63.

70. A method comprising:

depositing a layer on at least one slab face of a substrate, the layer comprising temporal transformation information.

71. The method of claim 70 wherein the layer further comprises spatial transformation.

72. The method of claim 70 wherein the layer further comprises spectral transformation.

73. The method of claim 70 wherein the layer is metallic.

74. The method of claim 70 wherein the layer is dielectric.

75. A product produced according to the method of claim 70.

76. A method comprising:

imprinting a hologram comprising temporal transformation information, on at least one surface of a support slab.

77. The method of claim 76 wherein the hologram further comprises spatial transformation information.

78. The method of claim 76 wherein the hologram further comprises spectral transformation.

79. The method of claim 76, further comprising pressing the support slab securely against an optical substrate.

80. The method of claim 76, further comprising bonding the support slab to an optical substrate.

81. A product produced according to the method of claim 76.

82. A method comprising:

selectively exposing a photosensitive substrate whose exposure changes a physical characteristic of the substrate, to make a volume hologram comprising temporal transformation information in the substrate.

83. The method of claim 82 wherein the volume hologram further comprises spatial transformation information.

84. The method of claim 82 wherein the hologram further comprises spectral transformation.

85. The method of claim 82 wherein the physical characteristic that is changed is at least one of absorptivity, index of refraction, and reflectivity.

86. A product produced according to the method of claim 82.

87. An apparatus comprising:

at least one input port;

at least one output port;

a planar waveguide comprising a planar boundary and a volume; and

a feedback structure comprising a plurality of diffractive elements exhibiting a positional variation in at least one of amplitude, spatial separation and spatial phase, the feedback structure further comprising a transfer function comprising temporal transformation information imprinted in a medium comprising the planar waveguide.

88. The apparatus of claim 87 wherein the medium comprises a material chosen from the group consisting of fused silica, polymer, silicon, and combinations thereof.

89. The apparatus of claim 87 wherein the at least one input port is a prism coupling.

90. The apparatus of claim 87 wherein the at least one output port is a prism coupling.

91. The apparatus of claim 87 where the transfer function further comprises spatial transformation information.

92. The apparatus of claim 87, where the transfer function comprises a conjugate Fourier transform $E_i^*(\omega)$ of a designed temporal waveform $E_i(t)$.

93. The apparatus of claim 87, wherein the volume hologram is thermally stabilized.

94. The apparatus of claim 93 wherein thermal stabilization is accomplished by a feedback signal.

95. The apparatus of claim 94 where the feedback signal is provided by a reference grating.

96. The apparatus of claim 87 further comprising the medium having a refractive index, wherein the diffractive elements comprise variations in refractive index of the medium.

97. The apparatus of claim 87, wherein the diffractive elements comprise profile variations in the planar boundary of the planar waveguide.

98. The apparatus of claim 87 wherein the diffractive elements comprise thickness variations in a layer of dielectric material overlaying a planar surface of the planar waveguide.

99. The apparatus of claim 87 wherein the planar waveguide comprises a bulk substrate.

100. The apparatus of claim 87, where each of the diffractive elements has a spherical contour and a center of curvature.

101 The apparatus of claim 100, wherein a plurality of the centers of curvature of the diffractive elements are coincident.

102. The apparatus of claim 101, wherein there is one input port and one output port, and where the input port and output port are located at respective conjugate image points of the plurality of the diffractive elements whose centers of curvature are coincident.

103. The apparatus of claim 87 where the transfer function further comprises spectral transformation information.

104. A volume hologram comprising a plurality of diffractive elements operative to accept an input optical signal incident from an input port, the input optical signal having a first spatial wavefront and a first optical spectrum, the volume hologram generating an output optical signal having a second spatial wavefront and a second optical spectrum, the output signal directed toward an output port, wherein the diffractive elements are configured to map the first spatial wavefront into the second spatial wavefront, and the diffractive elements are configured to map the first optical spectrum into the second optical spectrum.

105. The volume hologram of claim 104 wherein the diffractive elements are distributed in the thickness dimension.